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# TITLE

A STUDY OF COMPARATIVE GROWTH RATES

OF

LIVE AND BEETLE-KILLED TREES

By

F. P. Keen
Senior Entomologist

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August 1941

Forest Insect Laboratory
445 U. S. Court House
Portland, Oregon

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CONTENTS


| | Page |
|---|---|
| INTRODUCTION | 1 |
| Review of Past Work | 1 |
| Object of Present Study | 3 |
| RESULTS OF GROWTH COMPARISONS | 4 |
| I. Comparison between decadal growth of live index trees and beetle-killed trees of various classes on 4 individual 320-acre sample plots on the Deschutes, Fremont, and Rogue River National Forests for the period 1850-1940 | 5 |
| II. Comparison between decadal growth of live index trees and beetle-killed trees of various classes on 9 320-acre sample plots on the Sisters Area of the Deschutes National Forest (Data consolidated) | 6 |
| III. Comparison between the annual growth of index trees (class 3A-2A) and beetle-killed trees of various classes on 9 320-acre sample plots on the Sisters Area of the Deschutes National Forest (Data consolidated) | 7 |
| IV. Comparison between decadal growth of live class 3A-2A trees and beetle-killed trees of the same tree class on 18 320-acre plots in various parts of eastern Oregon (consolidated data) | 7 |
| V. Comparison between decadal growth of 53 beetle-killed trees and 100 live trees of the same stand structure from 9 320-acre check plots of the Sisters Area, Deschutes National Forest, Oregon | 9 |
| VI. Comparison between rate of growth of all Keen's tree classes with beetle-killed trees - Data on 44 beetle-killed trees from one 640-acre plot - Goodlow Mountain; and 395 green trees from 2 10-acre plots within the large 640-acre plot | 10 |

Page

Results of Growth Comparisons (continued)

VII. Comparison between decadal growth of 44 beetle-killed trees and 100 live trees of same tree classes on Goodlow Mountain plot, Fremont National Forest, Oregon 11

VIII. Comparison of annual growth between 44 beetle-killed trees of 1940, and 100 living trees of the same tree classes. Data from Goodlow Mountain plot, Fremont National Forest, Oregon 12

CONCLUSIONS 13

REFERENCES 15

## INTRODUCTION

One of the problems of tree selection by the western pine beetle (Dendroctonus brevicomis Lec.) has been the matter of comparative growth rates of beetle susceptible trees as contrasted with resistant trees.

The questions which have been raised include:

1. Do growth rates differ in live and beetle-killed trees?

2. Are growth patterns identical?

3. Is growth slower in beetle-killed trees than in live trees of the same tree class?

4. Is there a point where growth begins to lag in trees ultimately killed by beetles or is the relative growth of beetle killed and live trees steadily maintained?

5. Are there any characteristics of radial growth which would permit recognizing trees of high beetle risk before attack? And if so, how many years in advance of attack?

Some of these questions have been fully investigated and rather definite answers obtained. Other questions are still open for further investigation. But these questions are well worth full study because of the possibility of finding definite clues as to the reasons behind tree selection.

### Review of Past Work

A study of comparative growth rates of live and beetle-killed ponderosa pines was first started by the writer in 1925. In that year, on 38 pine-beetle survey plots in the Klamath region of southern Oregon and on the Modoc-Happy Camp area of northeastern California increment cores were taken from 677 pairs of comparable living and recently beetle-killed trees - i.e., those representing the 1924 attack. Micrometer increment core measurements were made by W. J. Buckhorn for the 10-year period 1915-1924 inclusive, and the growth patterns for living and dead trees were plotted for comparative purposes.

The results of this work were incorporated by H. L. Person with his work on the Cascadel Unit and published in his article on "Tree Selection by Western Pine Beetle".2/ These studies showed that 75 percent of trees were growing more slowly than the check trees, 10 percent were the same and 15 percent faster. Over 91 percent of all killed trees were growing less than 1 mm. in radius per year. The growth pattern graphs showed the killed trees growing at an average slower rate than the living trees on all 38 plots. Moreover this growth seemed to be more complacent and not subject to as marked fluctuations in good and poor years as the living trees. These graphs failed to indicate how long the trees killed in 1924 had been growing more slowly than the living trees but in most cases it appeared to be more than 10 years. Comparisons by diameter groups failed to explain any appreciable part of the large difference in growth between living and killed trees as being due to this factor. How much of this difference could be explained by tree class differences was not investigated; since this work was undertaken before tree classes were defined.

Further study by Person of the Cascadel plots4/ corroborated the fact that the killed trees were the slower growing. He also made a comparison by tree age classes without uncovering any additional information of striking character.

The work on tree classification by Dunning3/ and the writer5/ gave additional evidence as to the generally slower growth rates and vigor of susceptible trees and showed that certain tree classes of slow growth rates consistently appeared in the loss column more frequently than faster growing trees of comparable age or crown vigor.

Recently Salman7/ made an outstanding contribution to this subject by studying the ring patterns and growth rates of ponderosa pines on Timber Mountain, in Modoc County, California, and comparing these with crown conditions and evidence of incipient flathead infestations. His conclusions were that:

1. The types of trees in which most of the loss has been recorded, i.e. high risk trees, are generally the slower growing ones.

2. The slow growth rate is of recent origin and probably temporary, to be terminated either by death or recovery.

3. Growth abnormalities (missing rings) tend to occur more often in the high risk trees.

4. No apparent relation was found between crown characters used in rating risk and any particular type of growth pattern.

While these various studies have thrown considerable light on the comparative growth characteristics of susceptible, high risk or beetle killed trees as compared with living trees, still they have not answered all the questions that have been raised.

Salman's studies indicate that growth differences are of recent origin, but we should like to know how recent and how soon differences can be recognized. Are there any characteristics of growth patterns that would be helpful in recognizing high risk trees and if so how many years before death can these symptoms be diagnosed?

Object of Present Study

With the above questions in mind a study was undertaken in 1940 to explore further the growth characteristics, not of high risk trees, but of actual beetle-killed trees, to see if growth patterns or growth rate differences could have been used in predicting death.

During the regional pine beetle survey in August and September of 1940, crews were instructed to take increment cores from recently killed 1940 summer-brood trees on all survey plots; especially trees which appeared to be of non-susceptible types, especially vigor class A and B trees. Hundreds of increment cores were taken and 550 cores were measured by John Huber, Field Aide, in March 1941. These measurements were plotted and analyzed by R. C. Grant, Field Aide, and the writer and form the basis of the present report.

## RESULTS OF GROWTH COMPARISONS

There are many ways in which growth measurements might be measured and compared, and many variables enter into the problem. Some of these that might be considered include:

Dependent variable

1. Annual radial growth; or
2. Decadal radial growth

These may be either in terms of (a) actual millimeter measurements; (b) departure in millimeters from normal; (c) percent departure from normal; or (d) ratio of current to normal.

The determination of "normal" or average involves a decision as to whether to use the current or previous 10, 20, 30, or 50 year period; a moving mean; a weighted mean, or a cumulative mean.

Independent variables

1. Locality and site differences
2. Tree class differences
3. Diameter differences

The core measurements were made in terms of millimeters per year and decade and then converted to departures, percentage or ratio to normal. A large number of exploratory comparisons were made; depending upon the data available, with the idea of reducing to a minimum the influence of the independent variables mentioned above.

I. Comparison between decadal growth of live index trees (Class 3A-2A) and beetle-killed trees of various classes on 4 individual 320-acre sample plots on the Deschutes, Fremont, and Rogue River National Forests for period 1850-1940

The first comparison to be made was between the growth of live and that of beetle-killed trees on 4 sample 320-acre plots. The live trees were represented by 12 index trees (class 3A-2A) taken and measured in 1938 and the beetle-killed trees were represented by a varying number of trees killed in 1940, predominantly of vigor classes B, C, and D.

Decadal measurements in millimeters were plotted over years from 1850 or 1880 to 1940 (see Chart Ia). In a general way the two sets of trees showed the same growth pattern, except in some cases where A trees showed more fluctuation in growth. This may be explained by the tendency of A trees to respond in a greater degree to favorable or unfavorable conditions affecting growth.

The growth rates show that the beetle-killed trees were growing much more slowly than the index trees. For the period 1855 to 1935, the growth of beetle-killed trees averaged about 50 percent of the growth for living 3A trees. Subsequent to 1905, both sets of trees showed a sharp decline in growth rate.

By comparing the rate of current decadal growth to the previous 30-year mean we get a measure of the relative change in growth rate between live and beetle-killed trees (see Chart Ib). It appears from this comparison that the growth rate for beetle-killed trees had been dropping more rapidly than that of live trees for a considerable period of time. The point where beetle-killed tree growth began to lag varied decidedly and was not very conclusively demonstrated by these data.

The conclusions reached in this comparison were:

(1) the futility of comparing growth of beetle-killed trees with Class 3A trees, because their rate of growth was so greatly dissimilar.

(2) the data from individual plot comparisons were too weak for comparative purposes because of the small number of trees represented and the great variability in their growth rates and characteristics.

GRAPH Ia

# GROWTH COMPARISON BETWEEN LIVE AND BEETLE-KILLED TREES

BASIS

DATA FROM 4 320-ACRE CHECK PLOTS
DESCHUTES, FREMONT AND ROGUE RIVER NATIONAL FORESTS, OREGON

30 YEAR MEAN DECADAL GROWTH
CURRENT DECADAL GROWTH

MM GROWTH

## GOODLOWE MTN. PLOT

LIVE - 12 INDEX TREES

BEETLE-KILLED 44 TREES VARIOUS CLASSES

## DEADLOG BUTTE PLOT

LIVE - 12 INDEX TREES

BEETLE-KILLED 22 TREES VARIOUS CLASSES

## JOHNSON PRAIRIE PLOT

LIVE - 12 INDEX TREES

BEETLE-KILLED 21 TREES VARIOUS CLASSES

## SQUAW RIDGE PLOT

LIVE - 12 INDEX TREES

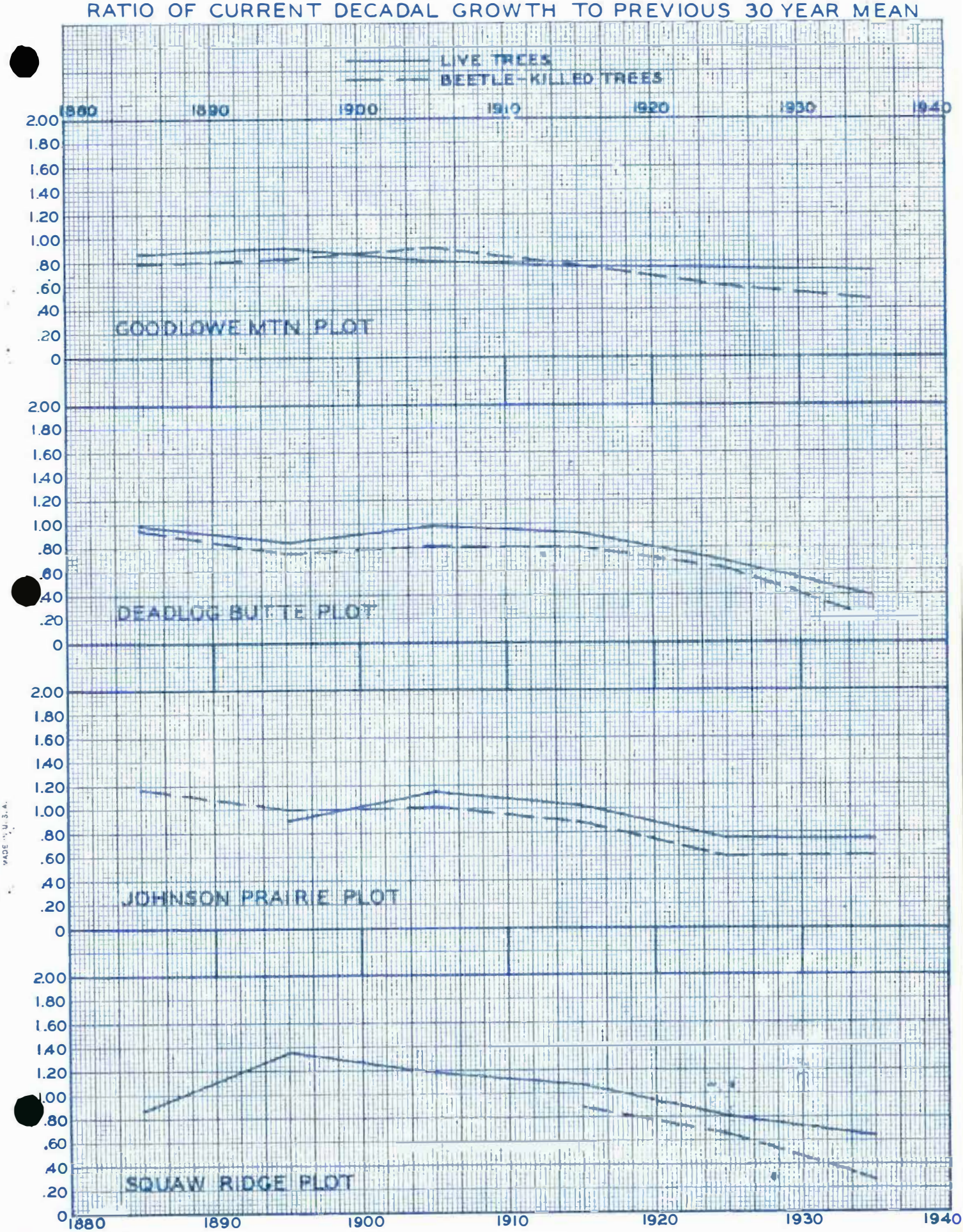
BEETLE-KILLED 10 TREES VARIOUS CLASSES

0 2 4 6 8 10 12 14 16 18 20

1850 1860 1870 1880 1890 1900 1910 1920 1930 1940

GRAPH I b

# RATIO OF CURRENT DECADAL GROWTH TO PREVIOUS 30 YEAR MEAN



II. Comparison between decadal growth of live index trees (Class 3A-2A) and beetle-killed trees of various classes on 9 320-acre sample plots on the Sisters Area of the Deschutes National Forest (Data consolidated)

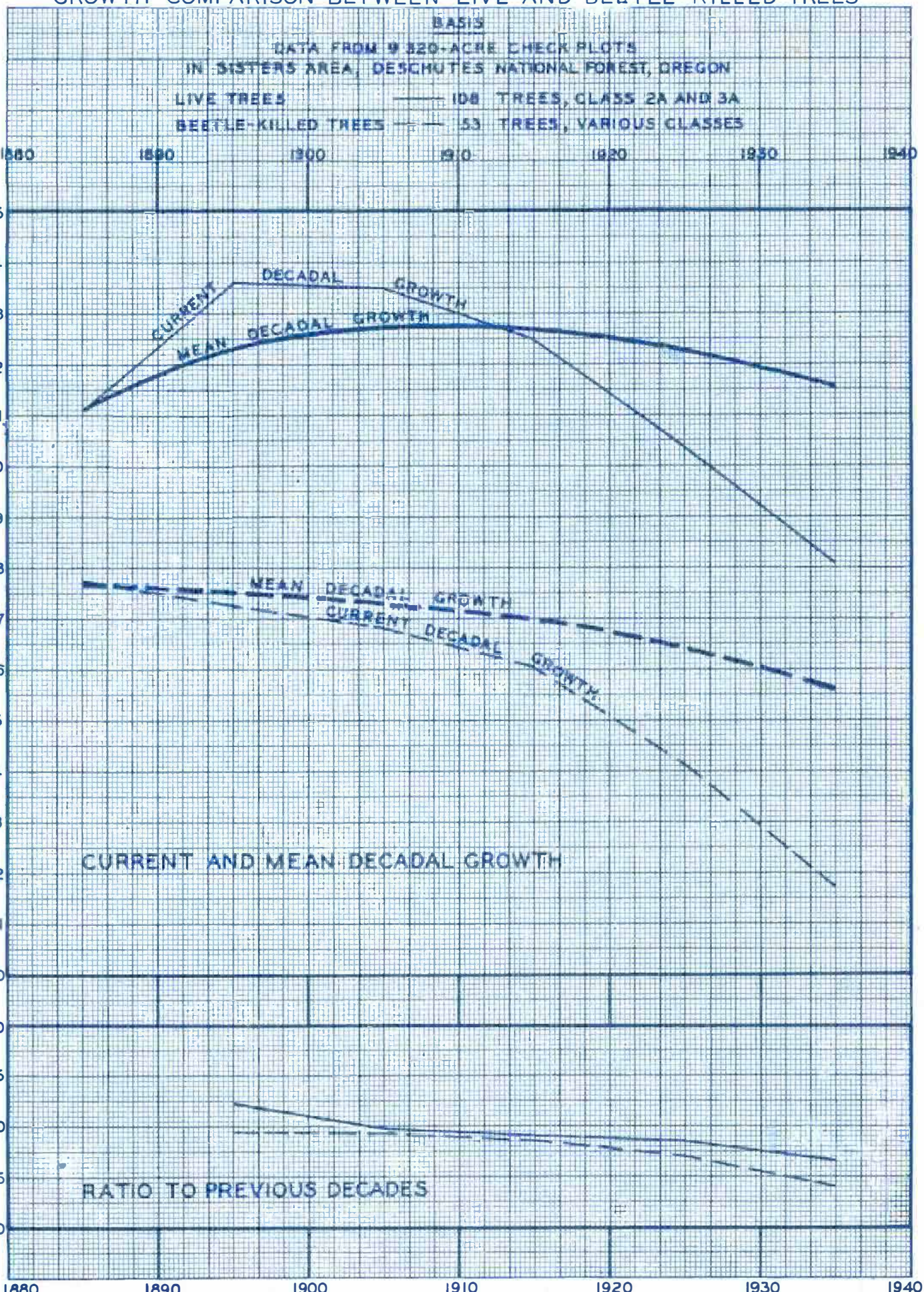
This comparison was similar to the last except that the data were strengthened by pooling the growth measurements taken on 9 sample plots in the Sisters Area. This made possible obtaining averages from 108 index trees (Class 3A) and 53 beetle-killed trees of various classes. These are shown in Graph II.

Decadal growth for the beetle-killed trees showed a steady decline in growth from 1880 while the index trees increased during the two decades 1890-1900 and 1900-1910 and then declined somewhat less rapidly. As in the previous example the average growth of the beetle-killed trees was approximately 50 percent that of the live index trees.

A comparison of the current decadal growth to that of the previous decade shows that the beetle-killed trees declined decade by decade at a somewhat faster rate than the living trees. This decline was especially rapid after 1915. This would indicate that the beetle-killed trees of 1940 had been inferior in growth capacity for a long time and that their weakened condition was not something of recent origin; although their decline was more rapid in recent decades.

# GRAPH II

## GROWTH COMPARISON BETWEEN LIVE AND BEETLE-KILLED TREES



III. Comparison between the annual growth of index trees (class 3A-2A) and beetle-killed trees of various classes on 9 320-acre sample plots on the Sisters Area of the Deschutes National Forest (Data consolidated)

In this comparison the same data were used as in comparison II except that the annual growth measurements for the past 10-year period 1930-39 were compared. (See Graph III.)

The beetle-killed trees showed a steady departure in current annual growth from mean annual growth beginning in 1933 while the green trees showed a marked departure in 1935 of a more abrupt character.

These data were inconclusive in showing anything more than that the beetle-killed trees were growing much more slowly than index trees and their rate of growth was declining more rapidly than these living index trees, even though the living trees also showed a marked decline in 1935 and 1936.

IV. Comparison between decadal growth of live class 3A-2A trees and beetle-killed trees of the same tree class on 18 320-acre plots in various parts of eastern Oregon (consolidated data)

In order to eliminate differences attributable to various tree classes only live and beetle-killed index trees (class 3A-2A) were used for the purpose of comparison. This required consolidating the data from a large number of plots in order to have enough beetle-killed class 3A-2A trees. On 18 320-acre plots 24 beetle-killed class 3A-2A trees of 1940 were found, and their average growth rate was compared with that of approximately 160 green trees on the same plots.

In spite of the fact that all trees included were class 3A-2A, the beetle-killed trees still showed an average decadal growth rate of only about 60% of that of living trees of the same class. Moreover this difference extended on back to 1850.

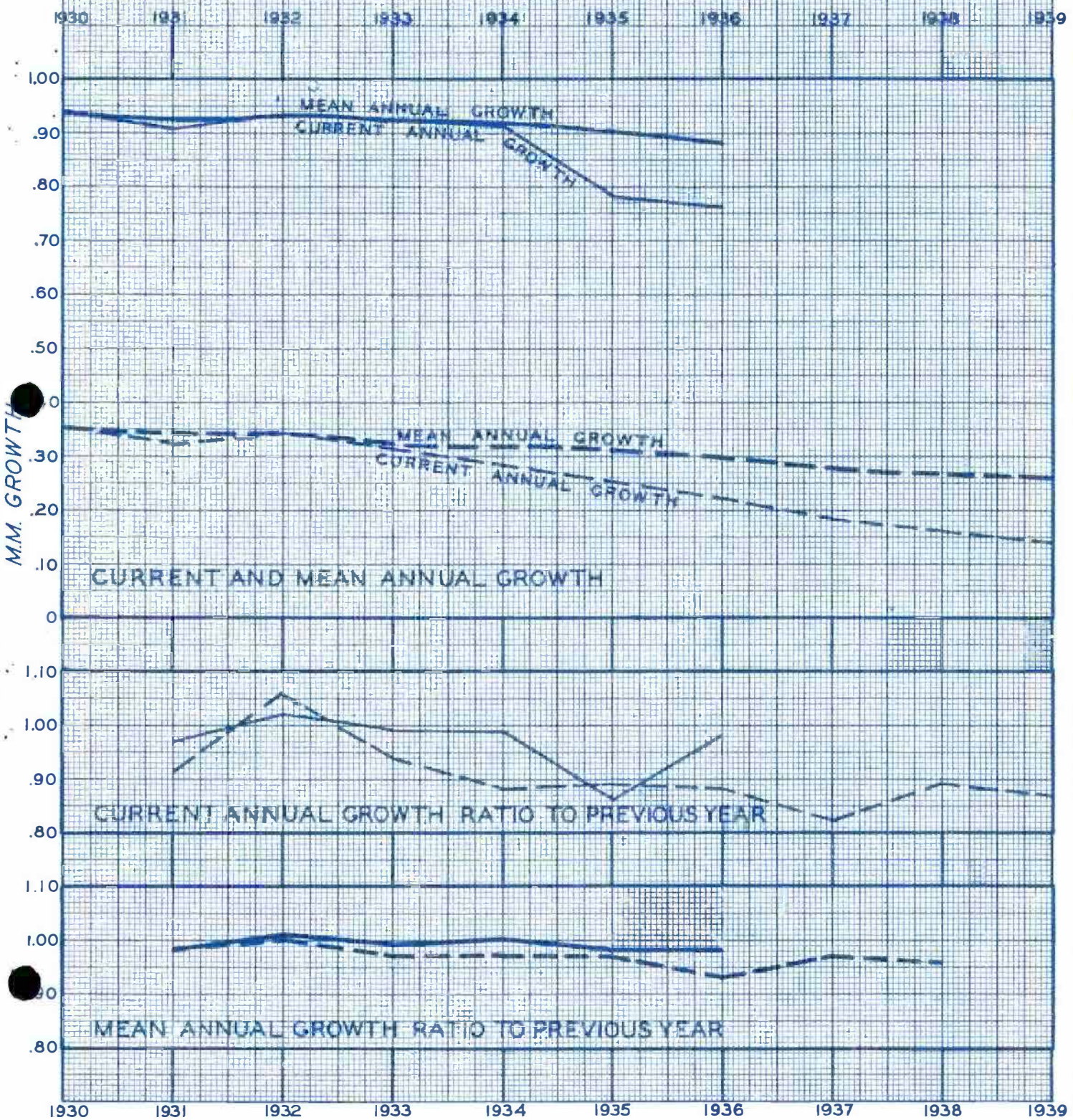
# GRAPH III

## GROWTH COMPARISON BETWEEN LIVE AND BEETLE-KILLED TREES

BASIS

DATA FROM 9 320-ACRE PLOTS
IN
SISTERS AREA, DESCHUTES NATIONAL FOREST, OREGON

LIVE TREES ——— 108 TREES, CLASS 2A AND 3A
BEETLE-KILLED TREES — — 52 TREES, VARIOUS CLASSES



The range in growth rate for the period 1900-09 was as follows:

Decadal Growth in MM. Period 1900-09

| | Maximum | Average | Minimum |
|---|---|---|---|
| 1. Living 3A trees | 18.1 | 13.8 | 9.5 |
| 2. Beetle-killed 3A trees | 18.0 | 7.5 | 2.5 |

Decadal Growth in MM. Period 1930-39

| | Maximum | Average | Minimum |
|---|---|---|---|
| 1. Living 3A trees | 7.6 | 6.1 | 3.7 |
| 2. Beetle-killed 3A trees | 7.7 | 1.9 | .3 |

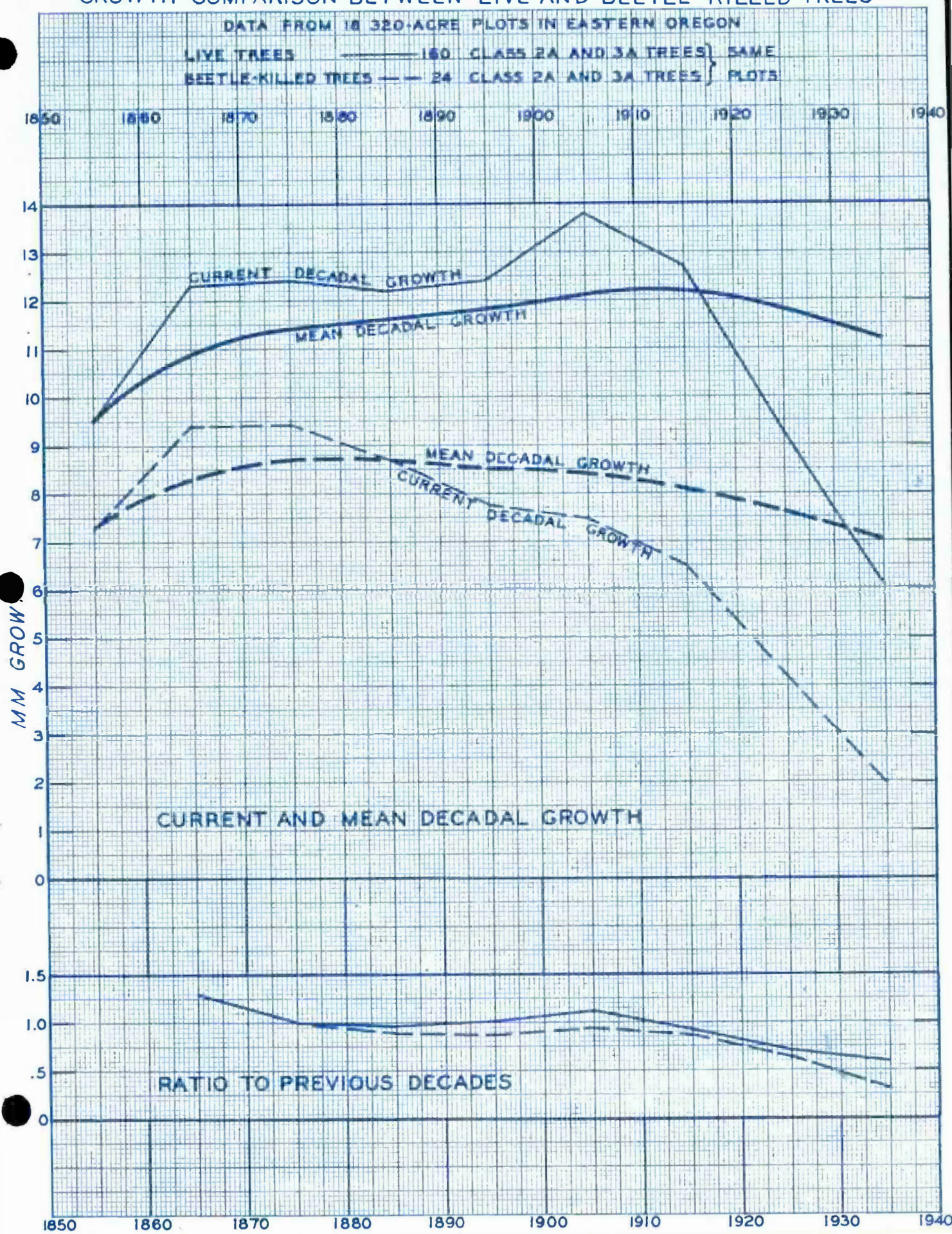
(1. Plot averages of 12 trees each for maximum and minimum - 160 tree average.)
(2. Individual tree measurements for maximum and minimum - 24 tree average.)

From the above it will be noted that the maximum growth of beetle-killed trees in 1900-09 and 1930-39 was up to the average maximum growth on all plots (not the individual tree maximum); the average growth in both periods was far below the average growth of living trees - 54% of the average in 1900-09 and 31% of the average in 1930-39.

The ratio to previous decade graph (Graph IV) shows that the living trees maintained or increased their growth rate up to 1905 and then began falling off. The beetle-killed trees had been falling off in growth rate since 1875. Both groups of trees fell off rapidly after 1915 due to the effect of drought.6/

# GRAPH IV

## GROWTH COMPARISON BETWEEN LIVE AND BEETLE-KILLED TREES



V. Comparison between decadal growth of 53 beetle-killed trees and 100 live trees of the same stand structure from 9 320-acre check plots of the Sisters Area, Deschutes National Forest, Oregon

In this comparison 53 1940 beetle-killed trees on 9 320-acre check plots of the Sisters Area were used and their growth rate compared with 100 living trees with the same proportion of various tree classes represented taken from 2 10-acre plots on one of the 320-acre plots. The distribution of tree classes was as follows:

| 1B | 2B | 2D | 3A | 3B | 3C | 3D | 4A | 4B | 4D | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 2% | 6% | 4% | 7% | 34% | 13% | 2% | 2% | 26% | 4% | 100% |

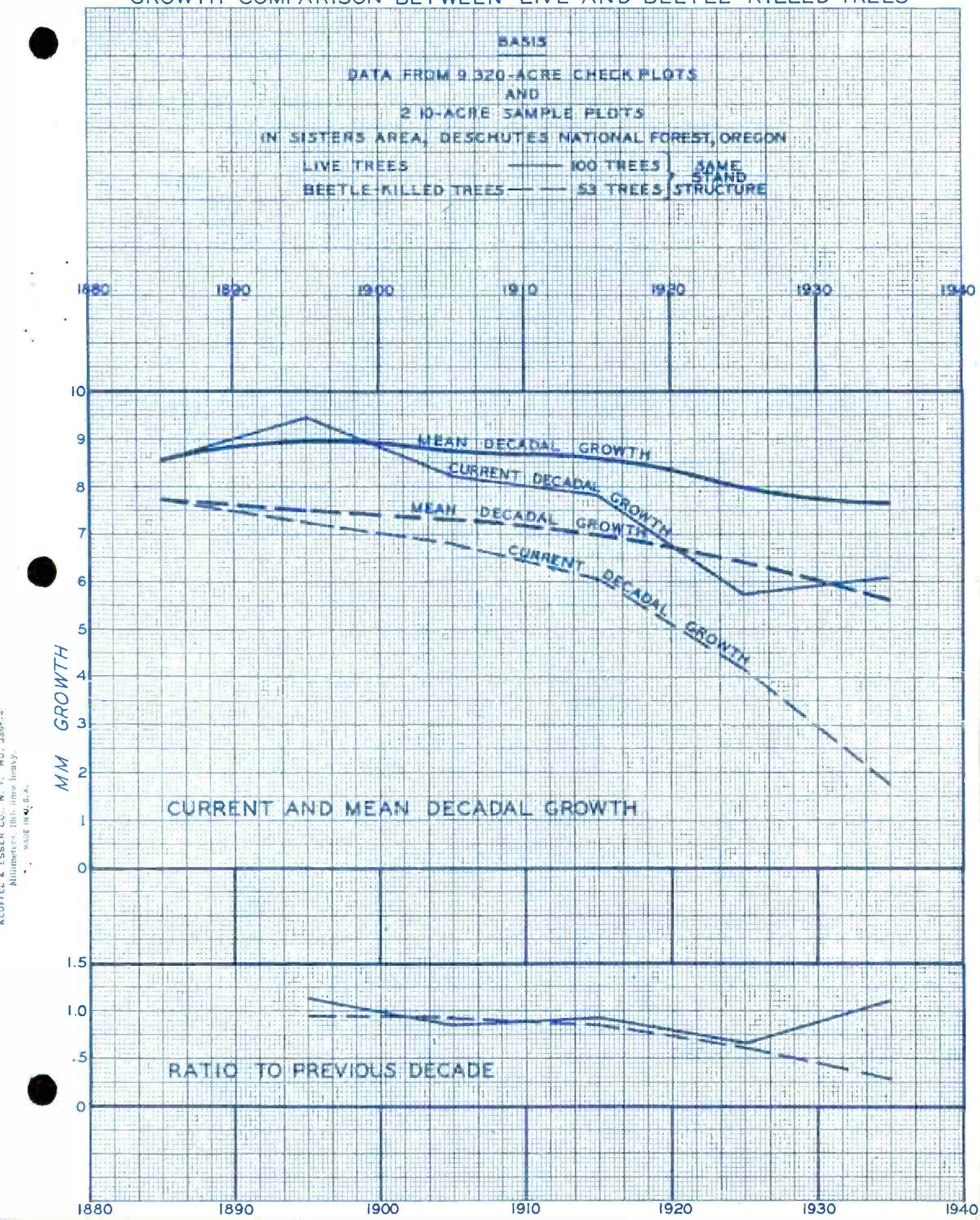
Even with this effort to obtain similar growth rates for live and beetle-killed trees, it was found that in the decade 1890-1900 the beetle-killed trees of 1940 were growing 23% more slowly than the average of trees of similar tree class; and in the decade 1920-1930 they were growing 27% more slowly (Graph V).

A comparison of the ratio of current growth to previous decade shows both sets of trees moving along together up to and including the decade 1920-30. Then the living trees improved in growth while the beetle-killed trees of 1940 declined. This indicates that the change was of recent origin; mainly because of the improvement in the live tree growth rate.

The flaw in this analysis is one of plot location because the green trees were taken from a limited area of 2 10-acre plots, while the beetle-killed trees were scattered over 9 320-acre plots.

GRAPH V

# GROWTH COMPARISON BETWEEN LIVE AND BEETLE-KILLED TREES



VI. Comparison between rate of growth of all Keen's tree classes with beetle-killed trees - Data on 44 beetle-killed trees from one 640-acre plot - Goodlow Mountain; and 395 green trees from 2 10-acre plots within the large 640-acre plot

Radial growth measurements from trees on the Goodlow Mountain plot permitted comparison of decadal growth for various tree classes with the growth rate of 1940 beetle-killed trees since 1850 (Graph VI).

An inspection of Graph VI shows that all of the resistant classes were growing at faster rates than the beetle-killed trees while susceptible classes5/ were growing more slowly. The average growth of beetle-killed trees marks the dividing line between these two groups of trees.

A close inspection of the graph also shows that the beetle-killed tree's pattern of growth closely followed that of the other tree classes, particularly the 4B's, until 1915 and then they showed a continuing downward trend, while most of the other classes showed some improvement in 1920-30. The growth of beetle-killed trees in the last decade, 1930-1940, was comparable to the slowest growing trees, Class 4C.

This analysis indicates:

(1) That the beetle killed trees of 1940 were complacent in their growth pattern for at least 50 years.

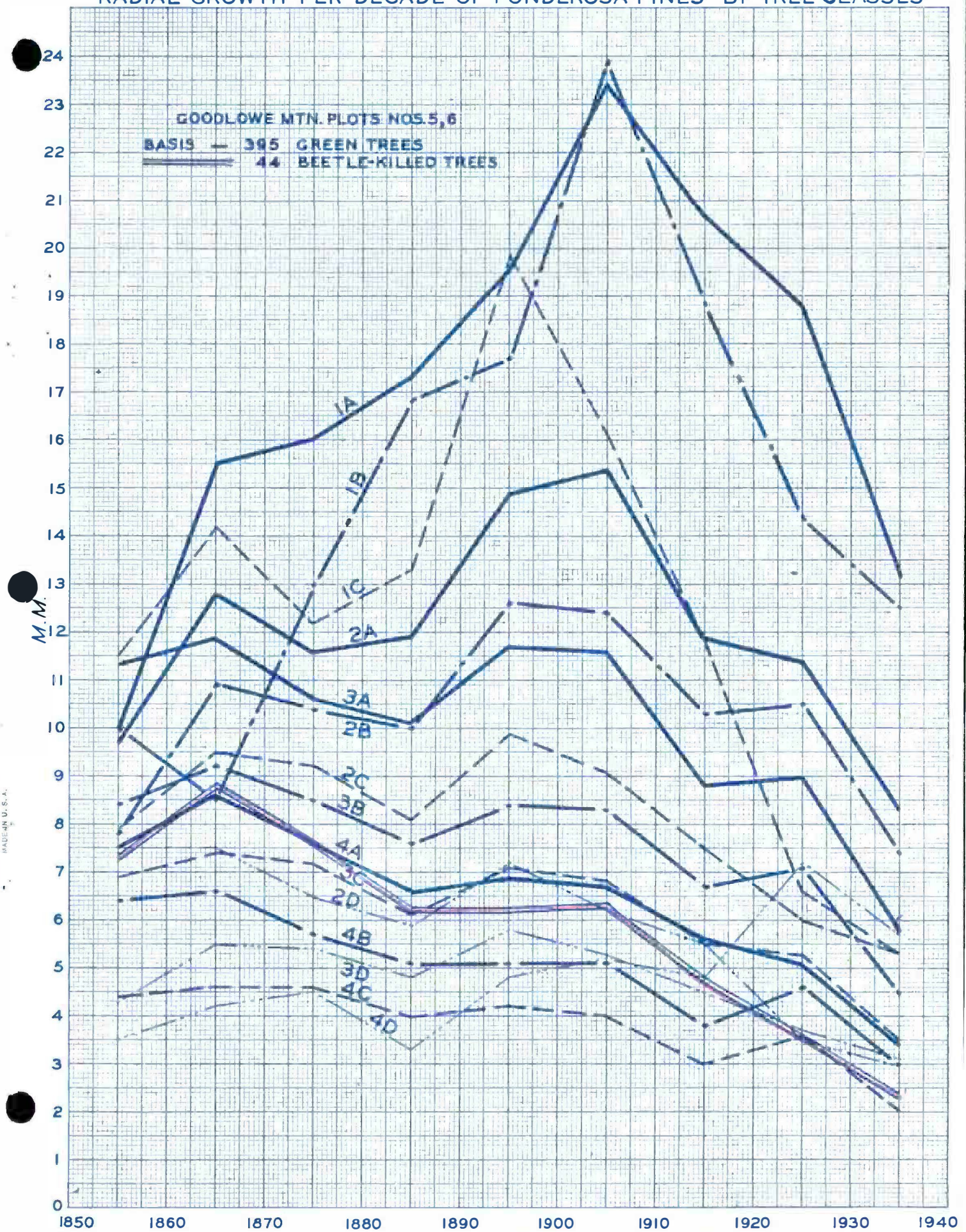
(2) That the average growth of beetle-killed trees represented the dividing line between resistant and susceptible tree classes. Susceptible classes on the average were growing more slowly than the beetle-killed trees, while resistant classes were growing more rapidly.

(3) That the growth pattern for beetle-killed trees took a downward turn as far back as the decade 1910-1920.

(4) That during the last decade, 1930-40, the beetle-killed trees were growing as slowly as the poorest tree class, Class 4C.

# GRAPH VI

## RADIAL GROWTH PER DECADE OF PONDEROSA PINES BY TREE CLASSES



VII. Comparison between decadal growth of 44 beetle-killed trees and 100 live trees of same tree classes on Goodlow Mountain plot, Fremont National Forest, Oregon

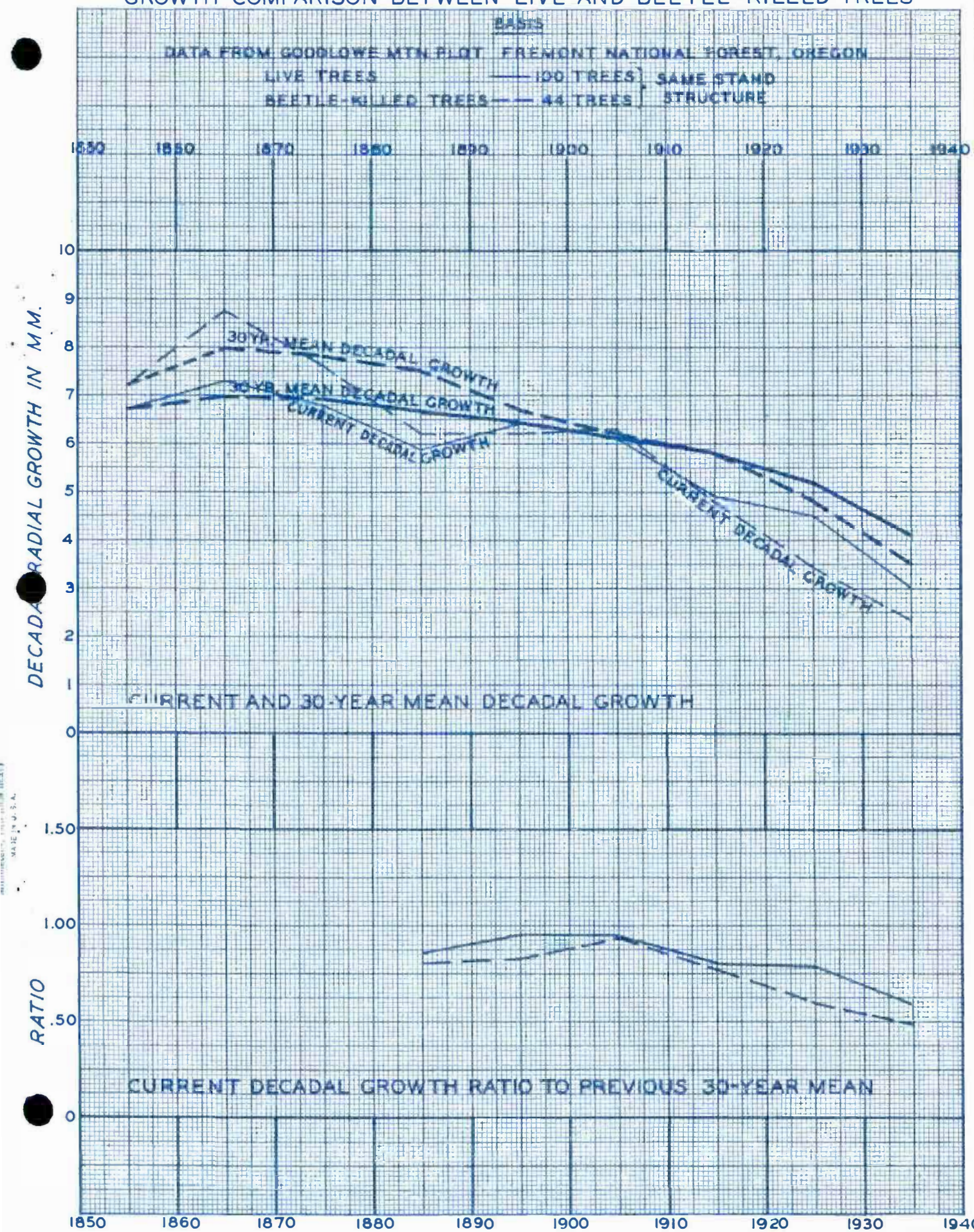
The data used in Analysis VI were apparently the most comparable of any used so far. They consisted of growth measurement of 44 1940 beetle-killed trees on the Goodlow Mountain 640-acre plot and measurements of 100 live trees from two 10-acre plots within this larger plot, with the same proportion of trees from the various tree classes as were represented in the killed stand.

The decadal growth comparisons are shown in Graph VII. It is evident that the selection of green trees gave actual radial growth measurements almost exactly comparable to those of the beetle-killed stand. In fact between 1850 and 1900 the beetle-killed trees of 1940 were growing faster than these particular live trees.

The way in which growth rates changed is best shown by the graph giving ratio of current decadal growth to previous 30-year mean. From this it is evident that the green and beetle-killed trees progressed together until the decade 1910-1920. Then the beetle-killed trees dropped away at a more rapid rate than the living trees. This indicates that growth differences date back to the 1910-1920 decade, probably to the slump in growth which started in 1917.6/

# GRAPH VII

## GROWTH COMPARISON BETWEEN LIVE AND BEETLE-KILLED TREES


BASIS
DATA FROM GOODLOWE MTN PLOT FREMONT NATIONAL FOREST, OREGON
LIVE TREES —— 100 TREES
BEETLE-KILLED TREES — — 44 TREES
SAME STAND STRUCTURE
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940
DECADAL RADIAL GROWTH IN MM.
10 9 8 7 6 5 4 3 2 1 0
30 YR. MEAN DECADAL GROWTH
30 YR. MEAN DECADAL GROWTH
CURRENT DECADAL GROWTH
CURRENT DECADAL GROWTH
CURRENT AND 30-YEAR MEAN DECADAL GROWTH
RATIO
1.50 1.00 .50 0
CURRENT DECADAL GROWTH RATIO TO PREVIOUS 30-YEAR MEAN
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940

VIII. Comparison of annual growth between 44 beetle-killed trees of 1940, and 100 living trees of the same tree classes. Data from Goodlow Mountain plot, Fremont National Forest, Oregon

Using the same material as discussed in Analyses VI and VII, annual growth measurements were made back to 1900 in order to see when the beetle-killed trees started on their growth decline.

An examination of Graph VIII shows that prior to 1917 the mean annual growth and in most years the annual radial growth of the 1940 beetle-killed trees was greater than that of comparable live trees, then from 1918 on to 1940 the beetle-killed tree growth rate declined more rapidly than the live tree growth.

The immediate cause of death appears to have occurred in 1935. At that time following a short slump in growth the green trees began to improve but the beetle-killed trees never recovered and gradually decreased in growth until the end came in 1940.

This graph shows both the long-term nature of the general retrogression in beetle-killed trees and the immediate short term effect prior to ultimate death.

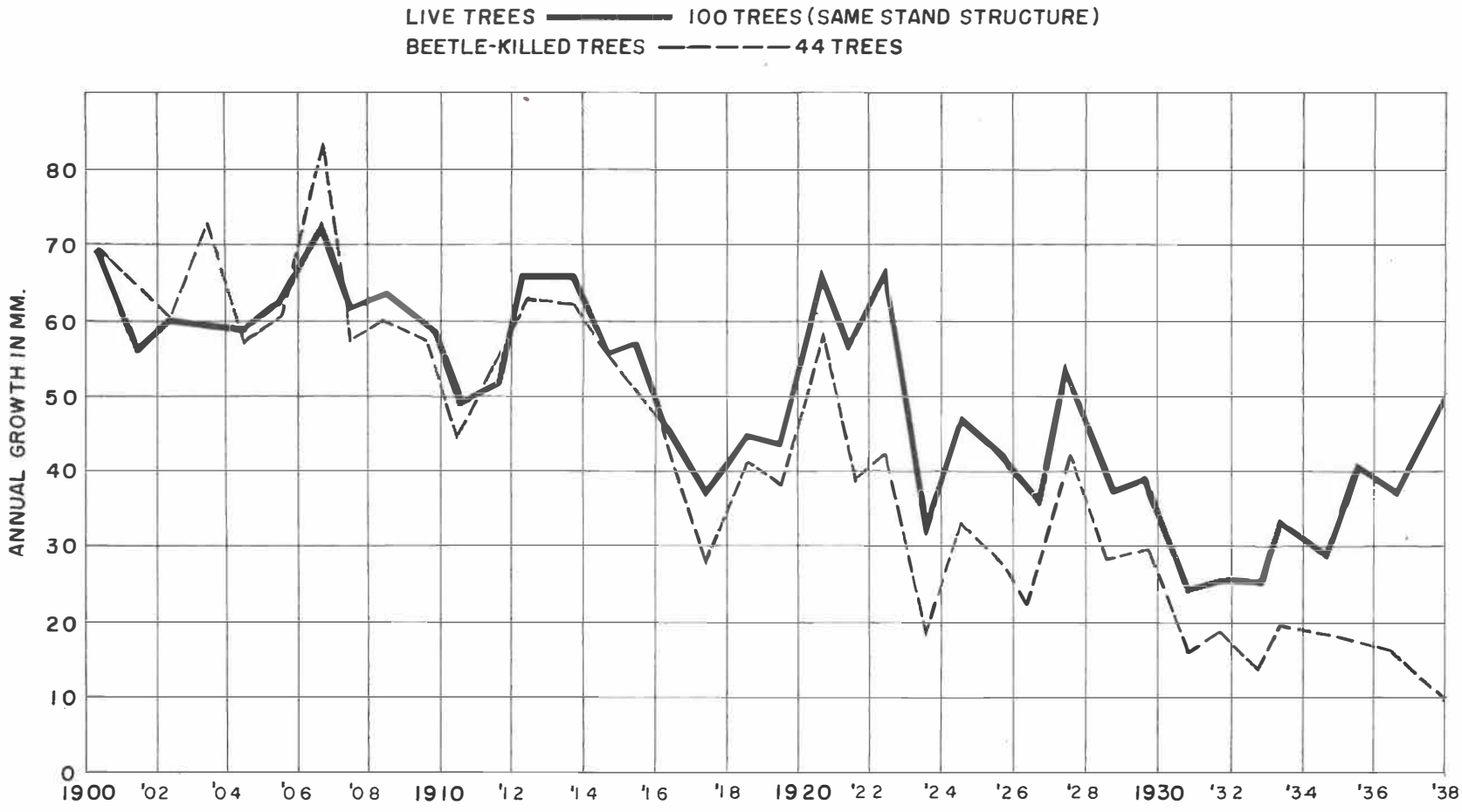
Graph VIII

FIGURE 25

# GROWTH COMPARISON BETWEEN LIVE AND BEETLE-KILLED TREES

1900—1938

DATA FROM GOODLOWE MTN. 640 ACRE PLOT, FREMONT NATIONAL FOREST OREGON



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## CONCLUSIONS

The exploratory study described in this report has further confirmed results of previous work in showing how radial growth rates of beetle-killed trees differ from comparable surviving trees. In addition some new evidence of growth characteristics were uncovered. The conclusions reached may be briefly summarized as follows:

1. Growth patterns of beetle-killed trees were similar to those of living trees, except that on the average beetle-killed trees were much more complacent in their growth and this characteristic was evident for 50 years or more preceding death.

2. The growth rate of beetle-killed trees is much slower than the general average of living trees in the stand, and this inferior growth rate has been characteristic of such trees for a long period of time. In this study, beetle-killed trees on the average were found to be growing less than 0.7 mm. per year during the past 30 years.

3. Within any tree class, the beetle-killed trees were found to be those growing more slowly than the average of that tree class.

4. Susceptible tree classes were found to be growing on the average more slowly than the average of beetle-killed trees in the decades preceding 1910, while resistant tree classes were found to be growing at a faster rate. In the decade preceding death, growth of the beetle-killed trees was further reduced to the minimum of any tree class (4C).

5. A general retrogression in growth rate of 1940 beetle-killed trees, more pronounced than that in living trees, started in 1917.

6. Death was preceded by five years of rapid growth decline in opposition to the growth trend of trees that lived.

7. Except for the change in growth rate, nothing was found in the pattern of beetle-killed trees which would be helpful in differentiating them from other slow-growing trees of susceptible tree classes.

While no startling discoveries were made in this study, the evidence does confirm previous work and tends to throw more light on the growth characteristics of susceptible and high risk trees.

It is evident that susceptible tree classes represent the slowest growing elements in a virgin stand, and that this characteristic is a long-term one extending back from 30 to 50 or more years.

High risk trees are those which have deteriorated in their growth rate beyond the point where recovery is possible. Within any tree class they represent that portion which is growing more slowly than the average of the class.

There is little hope of using radial growth characteristics for field determinations of high risk trees or in picking trees which are about to die, by a field examination of increment cores, even though this is a fairly reliable indicator of changes taking place in a tree's vigor and its resistance to insect attack.

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